CLAIMS

What is claimed is:

- 1 1. A hybrid battery power source for implantable medical use, comprising:
- 2 a primary battery;
- a secondary battery connected to receive power from said primary battery;
- 4 said secondary battery being adapted to power to an implantable medical device
- 5 designed for high energy electrical stimulation of body tissue for therapeutic purposes; and
- a charge control circuit powered by said primary battery and including voltage
- 7 reference and window comparator means for charging said secondary battery while limiting
- 8 charge/discharge excursions thereof in a manner that optimizes its output for high energy
- 9 medical device use.
- 1 2. A hybrid battery power source in accordance with Claim 1 wherein said charge
- 2 control circuit is a pulse output circuit adapted for variable pulse width or duty cycle control,
- 3 thereby allowing it to operate over a range of voltages output by said primary battery.
- 1 3. A hybrid battery power source in accordance with Claim 1 wherein said charge
- 2 control circuit is adapted to charge said secondary battery over a charge/discharge excursion
- 3 range that is below a maximum state-of-charge of said secondary battery and which is
- 4 selected to control discharge capacity fade and internal resistance increase during service of
- 5 said secondary battery.
- 1 4. A hybrid battery power source in accordance with Claim 1 wherein said voltage
- 2 reference and window comparator means includes first and second voltage comparators, said
- 3 first voltage comparator being adapted to initiate charging when said secondary battery falls
- 4 below a minimum voltage provided by a first voltage reference and said second voltage
- 5 comparator being adapted to terminate charging when said secondary battery is charged to a
- 6 maximum voltage provided by a second voltage reference.
- 1 5. A hybrid battery power source in accordance with Claim 4 further including a pulse
- 2 generator powered by said primary battery, said pulse generator being adapted to supply

- 3 pulsatile power to said first and second voltage comparators and said first and second voltage
- 4 references in order to conserve energy supplied by said primary battery to said charge control
- 5 circuit.
- 1 6. A hybrid battery power source in accordance with Claim 1 wherein said primary
- 2 battery is selected from the group consisting of lithium-carbon monofluoride batteries,
- 3 lithium-bromine chloride batteries, lithium-sulfuryl chloride batteries, lithium thionyl
- 4 chloride batteries, lithium-manganese dioxide batteries, lithium-silver vanadium oxide
- 5 batteries and lithium-iodide batteries, and wherein said secondary battery is selected from the
- 6 group consisting of lithium-ion batteries.
- 1 7. A hybrid battery power source in accordance with Claim 1 further including a voltage
- 2 boost circuit that facilitates charging of said secondary battery at a voltage that is higher than
- 3 a voltage output of said primary battery.
- 1 8. A hybrid battery power source in accordance with Claim 7 wherein said voltage boost
- 2 circuit comprises one of an inductive element or flyback transformer.
- 1 9. A hybrid battery power source in accordance with Claim 7 wherein said voltage boost
- 2 circuit comprises a capacitive charge storage device.
- 1 10. A hybrid battery power source in accordance with Claim 9 wherein said voltage boost
- 2 circuit is adapted to produce charging pulses of sufficiently short duration to reduce the
- 3 discharge rate of said primary battery to a level that is compatible with the maximum
- 4 discharge current capacity thereof.
- 1 11. An implantable medical device for high energy electrical stimulation of body tissue
- 2 for therapeutic purposes, comprising:

3 a pair of electrical contacts adapted to provide electrical stimulation to body tissue; energy storage means adapted to provide electrical energy to said electrical contacts; 4 5 switching means adapted to periodically interconnect said energy storage means to 6 said electrical contacts; and 7 a hybrid battery power source adapted to provide power to said energy storage means 8 and including: 9 a primary battery; 10 a secondary battery connected to receive power from said primary battery and to 11 provide power to said energy storage means; and 12 a charge control circuit powered by said primary battery and including voltage 13 reference and window comparator means for charging said secondary battery while limiting 14 charge/discharge excursions thereof in a manner that optimizes its output for high energy

- 1 12. An implantable medical device in accordance with Claim 11 wherein said charge
- 2 control circuit is a pulse output circuit adapted for variable pulse width or duty cycle control,
- 3 thereby allowing it to operate over a range of voltages output by said primary battery.
- 1 13. An implantable medical device in accordance with Claim 11 wherein said charge
- 2 control circuit is adapted to charge said secondary battery over a charge/discharge excursion
- 3 range that is below a maximum state-of-charge of said secondary battery and which is
- 4 selected to control discharge capacity fade and internal resistance increase during service of
- 5 said secondary battery.

medical device use.

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- 1 14. An implantable medical device in accordance with Claim 11 wherein said voltage
- 2 reference and window comparator means includes first and second voltage comparators, said
- 3 first voltage comparator being adapted to initiate charging when said secondary battery falls
- 4 below a minimum voltage provided by a first voltage reference and said second voltage
- 5 comparator being adapted to terminate charging when said secondary battery is charged to a
- 6 maximum voltage provided by a second voltage reference.

- 1 15. An implantable medical device in accordance with Claim 14 further including a pulse
- 2 generator powered by said primary battery, said pulse generator being adapted to supply
- 3 pulsatile power to said first and second voltage comparators and said first and second voltage
- 4 references in order to conserve energy supplied by said primary battery to said charge control
- 5 circuit.
- 1 16. An implantable medical device in accordance with Claim 11 wherein said primary
- 2 battery is selected from the group consisting of lithium-carbon monofluoride batteries,
- 3 lithium-bromine chloride batteries, lithium-sulfuryl chloride batteries, lithium thionyl
- 4 chloride batteries, lithium-manganese dioxide batteries, lithium-silver vanadium oxide
- 5 batteries and lithium-iodide batteries, and wherein said secondary battery is selected from the
- 6 group consisting of lithium-ion batteries.
- 1 17. An implantable medical device in accordance with Claim 11 further including a
- 2 voltage boost circuit that facilitates charging of said secondary battery at a voltage that is
- 3 higher than a voltage output of said primary battery.
- 1 18. An implantable medical device in accordance with Claim 17 wherein said voltage
- 2 boost circuit comprises one of an inductive element or flyback transformer.
- 1 19. An implantable medical device in accordance with Claim 17 wherein said voltage
- 2 boost circuit comprises a capacitive charge storage device.
- 1 20. An implantable medical device in accordance with Claim 19 wherein said voltage
- 2 boost circuit is adapted to produce charging pulses of sufficiently short duration to reduce the
- 3 discharge rate of said primary battery to a level that is compatible with the maximum
- 4 discharge current capacity thereof.
- 1 21. A method for powering an implantable medical device designed for high energy
- 2 electrical stimulation of body tissue for therapeutic purposes, comprising:

- 3 providing a primary battery;
- 4 providing a secondary battery and connecting it to receive power from said primary
- 5 power battery;
- 6 connecting said secondary battery to power said implantable medical device;
- 7 periodically monitoring the charge state of said secondary battery; and
- 8 periodically charging said secondary battery by way of said primary battery while
- 9 limiting charge/discharge excursions of said secondary battery in a manner that optimizes its
- 10 output for high energy medical device use.
- 1 22. A method in accordance with Claim 21 wherein said charging is performed under
- 2 variable pulse width or duty cycle control over a range of voltages output by said primary
- 3 battery.
- 1 23. A method in accordance with Claim 21 wherein said charging comprises charging
- 2 said secondary battery over a charge/discharge excursion range that is below a maximum
- 3 state-of-charge of said secondary battery and which is selected to control discharge capacity
- 4 fade and internal resistance increase during service of said secondary battery
- 1 24. A method in accordance with Claim 21 wherein said monitoring comprising a first
- 2 periodic comparison to initiate charging when said secondary battery falls below a minimum
- 3 voltage and a second periodic comparison to terminate charging when said secondary battery
- 4 is charged to a maximum voltage.
- 1 25. A method in accordance with Claim 24 wherein said first and second comparisons are
- 2 performed using pulsatile energy delivered by said primary battery in order to conserve
- 3 energy supplied by said primary battery for said first and second comparisons.
- 1 26. A method in accordance with Claim 21 wherein said primary battery is selected from
- 2 the group consisting of lithium-carbon monofluoride batteries, lithium-bromine chloride
- 3 batteries, lithium-sulfuryl chloride batteries, lithium thionyl chloride batteries, lithium-
- 4 manganese dioxide batteries, lithium-silver vanadium oxide batteries and lithium-iodide

- 5 batteries, and wherein said secondary battery is selected from the group consisting of lithium-
- 6 ion batteries.
- 1 27. A method in accordance with Claim 21 further including voltage boosting in order to
- 2 charge said secondary battery at a voltage that is higher than a voltage output of said primary
- 3 battery.
- 1 28. A method in accordance with Claim 27 wherein said voltage boosting comprises
- 2 inductive voltage boosting.
- 1 29. A method in accordance with Claim 27 wherein said voltage boosting comprises
- 2 capacitive voltage boosting.
- 1 30. A method in accordance with Claim 29 wherein said voltage boosting comprises
- 2 producing charging pulses of sufficiently short duration to reduce the discharge rate of said
- 3 primary battery to a level that is compatible with the maximum discharge current capacity
- 4 thereof.